Hello, Chinese Ethnic and Folk Dances

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Fig. 1. Display of Chinese ethnic and folk Dances in our system. Left: Tibet dance. Middle: Kazakh dance. Right: Yi people's dance.

***Abstract*—China has a wealth of ethnic and folk dances, which are our national precious intangible cultural heritage. It is our obligatory responsibility to protect and inherit these precious treasures. This work aims to apply computer graphics and augmented reality (AR) techniques to the dynamic display of folk dances. We use the real motion capture data of the dance artists to drive virtual characters' dance performances. Meanwhile costumes and stage scenes with ethnic characteristics help to foil the atmosphere of dance. Our work not only solves the problem of unable to transmit motion capture data due to copyright restrictions, but also has a good sense of immersion and interactivity, which plays an active role in promoting the protection and inheritance of action-type intangible cultural heritage.**

***Keywords*—Ethnic and folk dances, Mobile augmented reality, Motion capture, 3D character animation, Spline Curve**

I. Problem Statement

Chinese dance art has a long history, consisting of a variety of dance forms. China is a unified multi-ethnic country composed of 56 officially recognized ethnic groups, and each ethnic group has its own folk dances. These dances are the precious cultural wealth of the Chinese nation. However, due to the influence of unstable inheritance methods and backward regional development[1], some ethnic folk dances are on the verge of extinction. Therefore, the conservation of ethnic and folk dances has been a high priority for us.

Traditional methods of preservation and inheritance include text, images and video. The written record is abstract and ambiguous. The picture is a static 2D image, which can only reflect the movement at a certain moment of the dance, lacking of coherence and dynamic performance. Although the video method overcomes the shortcoming of motionlessness, the movement of the occluded part of the body is uncertain under self-occlusion. Furthermore, the video can only record the 2D human movement, but cannot provide accurate 3D human movement. At present, relatively advanced motion capture technology can record dances completely and accurately. Based on motion capture data, automatic generation of Labanotation for national dynamic art digitization is a new method that uses dance symbols to record folk dances[2]. However, expensive professional equipment and copyright issues make it difficult to provide motion capture data directly to ordinary users.

With the rapid development of virtual reality and augmented reality technology, the use of modern techniques

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can greatly enhance the interactive entertainment in dance shows. Meanwhile, as mobile intelligent terminals innovate fast, the digital display of intangible cultural heritage based on mobile augmented reality technology has become a new trend in the protection and inheritance of intangible cultural heritage[3]. The purpose of this work is to apply computer graphics and augmented reality technology to the dynamic display of ethnic and folk dances, and to use the motion capture data collected by real dance artists to drive the dance performance of virtual characters. It positively promotes the protection and inheritance of action intangible cultural heritage, and has important practical significance and profound cultural connotation.

II. Our Novelties

Our work focuses on using motion capture data to drive the dance of virtual character. In order to get a better system experience, we make the following innovations.

A. Propose a motion capture data-driven method for displaying dances.

Since the motion capture data is collected by expensive and professional equipment, it cannot be transmitted due to copyright restrictions. We propose a motion capture data-driven method to the performance of virtual characters. It not only overcomes the transmission problem, but also has a good sense of immersion and interactivity. In order to simulate the performance process of real dance actors, our work designs and simulates the three stages of the dance performance: the stage of the debut, performance and exit. During the stage of debut and exit, the movement path of virtual characters is effectively planned based on spline curve, which makes it more natural and realistic. In order to ensure the smoothness of folk dances display, we use the animation state machine to realize the smooth transition of three stages.

B. Implement an ethnic dynamic art display system based on mobile augmented reality.

We use the motion capture data obtained from professional authorities, combined with skinned mesh to drive the virtual characters' dances. Our AR system uses four maker images with ethnic characteristics to guide the speech introductions and dynamic display of folk dances. Costumes and stage scenes with ethnic characteristics help to enhance a good sense of immersion. In order to solve the problem of dynamic display of costume during dance, we control ethnic costume based on bone child nodes to implement dynamic simulation of virtual character's costume.

III. System Architecture

Our system is developed by game engine Unity and augmented reality SDK Vuforia. We aim to apply computer graphics and AR technology to the dynamic display of folk dances. In order to simulate the real dancers' performance flow, we design five blocks to implement it.

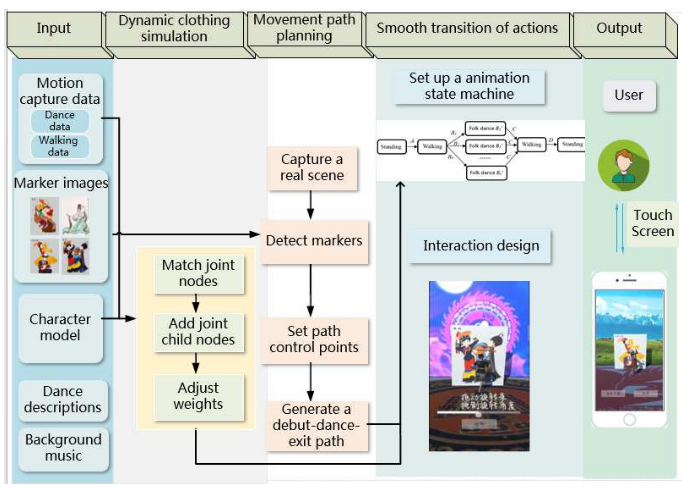

Fig. 2. System architecture.

Fig. 2 illustrates the system architecture, in the first block, our input data includes motion capture data, marker images, character models, dance descriptions and background music. And then in clothing dynamic simulation layer, we add matched bone nodes to binding the character model and motion capture data in 3ds Max. Since the motion capture data only contains the information of human joints, we need to create additional child nodes and adjust the weight of child nodes affected by bone nodes to achieve dynamic simulation of clothing. Next, when the user scans the marker images, a "debut-dance-exit" path will be generated for the corresponding character model. In addition, the animation state machine is used to realize the smooth transition of the action sequence of the characters. And during the dance, users can pause at any time to enjoy the dance from multiple angles. Finally, the application is packaged as an Android package and is available to run on an Android mobile smart terminal.

IV. Technical Highlights

In this section, we introduce the key technologies in our work.

A. Motion path planning of virtual character.

In order to simulate the performance process of real actors, we designed three stages: the debut, dance and exit of characters. When planning the path of debut and exit, it is simple to realize the discounted path, but it is too mechanical and lacks the sense of reality. The smooth curve obtained by a given series of control points is called spline curve. It is used to plan the movement path of the characters in line with the walking path of the real actors, which increases the sense of reality of the performance. Therefore, in this paper, we use the closed Catmull-Rom spline curve of six control points to generate the movement path of dancers. According to whether all the control points are on the spline curve, the spline curve can be divided into interpolation spline curve and approximation spline curve. Since each control point of the interpolating spline is on the curve, it is more appropriate to specify the animation path. In addition, compared with high-order and low-order spline curves, cubic spline interpolation curve provides a reasonable compromise between flexibility and computation, avoiding the disadvantages of large computation and poor flexibility. We set the starting point (i.e., the end point) $\boldsymbol{P}_0$, the initial point $\boldsymbol{P}_3$ of the dance display and four points ($\boldsymbol{P}_1$, $\boldsymbol{P}_2$, $\boldsymbol{P}_3$, $\boldsymbol{P}_4$) with large curvature on the closed motion path as the control points of the spline curve, as shown in Fig. 3.

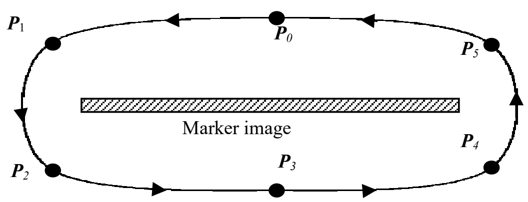

Fig. 3. Spline curve path generated by control points

The Catmull-Rom spline curve is smooth at the control point and between adjacent control points, and there is no obvious defect. Therefore, the closed Catmull-Rom spline curve is adopted to plan the motion path of the virtual character model. Let $\boldsymbol{P}_{k-1}$, $\boldsymbol{P}_k$, $\boldsymbol{P}_{k+1}$ and $\boldsymbol{P}_{k+2}$ be control points, the cubic function of Catmull-Rom spline curve can be defined as:

$$
\begin{aligned}
\boldsymbol{F}(\boldsymbol{u}) &= \frac{1}{2}\left(\boldsymbol{P}_{k+2} - 3\boldsymbol{P}_{k+1} + 3\boldsymbol{P}_k - \boldsymbol{P}_{k-1}\right)\boldsymbol{u}^3 \\
&+ \frac{1}{2}\left(-\boldsymbol{P}_{k+2} + 4\boldsymbol{P}_{k+1} - 5\boldsymbol{P}_k + 2\boldsymbol{P}_{k-1}\right)\boldsymbol{u}^2 \\
&+ \frac{1}{2}\left(\boldsymbol{P}_{k+1} - \boldsymbol{P}_{k-1}\right)\boldsymbol{u} + \boldsymbol{P}_k \quad (\boldsymbol{0} \le \boldsymbol{u} \le 1)
\end{aligned} \tag{1}
$$

The corresponding spline curves can be generated by using the formula above, and the spline curves can be connected into closed ones by piecewise interpolation.

B. Smooth transition of virtual character action sequences.

The animation state of the characters in this system includes standing, walking and dancing. The smooth transition of these three states is implemented by the animation state machine which controls the character model to perform a specific action at a given time. The animation state corresponds to a specific action and is the basic unit of the animation state machine. It can be implemented by a directed graph, with nodes representing states and arcs representing triggering conditions. The animation state machine of this system is shown in Fig. 4. It starts from standing state and changes to walking state after triggering condition *A*. According to the identification picture identified by the user, the state of the character switches to the corresponding dance B_i'. When the dance display ends, the walking state is triggered and the character returns to the backstage. When the character reaches the destination, animation state switches to standing state.

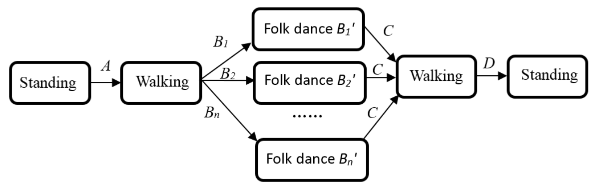

Fig. 4. The animation state machine

C. Dynamic simulation of virtual character's costume.

As the motion capture data only includes the movement of human bones, the costume cannot be displayed dynamically during the dance. Moreover, since the cloth is non-rigid, the animation of a deformable object is much more time-consuming than that of a rigid object because it incurs complex numerical computations[4]. Therefore, it is hard to achieve physical simulation in real time. To solve this problem, we design a simplified dynamic simulation method for virtual character's costume. Firstly, we create a 3D model with textures for each character. Next, we create appropriate human skeletons based on motion capture data, and then add child nodes of human skeleton to adjust the weight of vertex of clothing model affected by bone nodes. The newly added bone child nodes form a hereditary relationship with the skeleton bone nodes, jointly realizing the control of the vertex of the clothing. Finally, fine-tune the location and number of bone nodes. By adding bone child nodes to simulate clothing fabric, the control of clothing vertex is refined, but the complexity of adjustment is increased. In our experiments, we add nearly a hundred bone child nodes for each character to greatly reduce the mutual penetration between the hem and limbs.

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